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A User's Guide to LAMPAT and ANSYS

by Robert P. Kaste

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Abstract

LAMPAT and ANSYS are analysis tools that can be used together to evaluate mechanical integrity of structures of laminar construction. The two codes originate from two different areas of analysis. Their default coordinate systems have different orientations. To properly examine a structure, the directional properties used by LAMPAT must be transformed into the proper input coordinate directional properties for ANSYS. This has been done for some time already, but as the structures being analyzed become more complex, this coordinate system transformation has become a tool requiring some additional thought. This report describes using cylindrical and Cartesian coordinate system orientations and local element coordinate system results within ANSYS to facilitate the analysis of laminate structures with ply layers parallel to curvilinear profiles.

Contents

List of Figures	v
List of Tables	vii
1. Introduction	1
2. Method	4
3. Conclusions	7
Appendix A. Coordinate Transformations in LAMPAT	9
Appendix B. Material Input for Smearing and Coordinate Transformation (DBMAT.IN)	15
Appendix C. Material Input for ANSYS (MAT.FIL)	19
Appendix D. ANSYS Input File (MODEL.TXT)	25
Appendix E. Data Transfer Macros (MACRO.WRITE)	33
Distribution List	41
Report Documentation Page	47

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List of Figures

Figure 1. Typical simple laminate structures.	2
Figure 2. A laminate structure requiring more complex coordinate orientations for analysis purposes.....	2
Figure 3. Alignment of local coordinate systems in ANSYS to facilitate analysis and postprocessing.....	3
Figure 4. Curved cross-section laminate structure.	5
Figure A-1. Coordinate systems in LAMPAT and ANSYS.	11
Figure A-2. Coordinate transformations for consistency within ANSYS and LAMPAT.	12
Figure A-3. Comparison of default, global Cartesian, and local coordinate systems on the element coordinate systems for alignment of laminae properties and results.....	13

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List of Tables

Table A-1. Permutations of coordinate rotations.....	12
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1. Introduction

To properly analyze orthotropic laminar composites in structural finite element codes such as ANSYS,^{*} it is necessary to align the coordinate systems of the laminae with the coordinate system of the analysis code.¹ This can be accomplished using the LAMPAT² code.

Typically, relatively simple laminate geometries have been analyzed in ANSYS, such as problems with structures wound on cylindrical mandrels or items machined from a ply-stacked composite stock, as shown in Figure 1. LAMPAT uses the local coordinate system reference for each element for smearing and unsmeared the element data. Models of these simple structures can be constructed and described with a single global coordinate system, which is the local coordinate orientation for all elements. Thus, it is relatively easy to properly align the material properties for analysis in ANSYS and LAMPAT. The global coordinate system may be cylindrical or Cartesian (Figure 1). ANSYS utilizes the element coordinate directions and the smeared properties of the elements to perform its analysis on an approximated laminate structure. LAMPAT analyzes the effect of the stresses on each element, or approximated laminate, to resolve the stresses and strains in the individual plies within that laminate. The material properties and orientations of each ply are contained in the LAMPAT files.

This report describes how to use LAMPAT and ANSYS to analyze more complex geometry laminate structures. The structure in Figure 2 represents a laminar structure that results from ply stacking into a mold or onto a pattern of complex geometry to produce a final or near net shape part. The intralaminae coordinate referencing must be performed as it was previously, but additional effort is required to assure that the laminate is properly oriented, and the resultant stresses are referenced to the local coordinate system for each element.

Using consistent local coordinate directions through the model greatly simplifies the postprocessing analysis of the results. Typically, when postprocessing data from LAMPAT to ANSYS, the failure modes, failure criteria, and safety factors of the various regions in the model must be determined to properly observe the model's response to the loading. For example, if a structure like the one in

^{*} Swanson Analysis Systems, Inc., P.O. Box 65, Johnson Road, Houston, PA 15342-0065.

¹ Bogetti, T. A., C. P. R. Hoppel, and B. P. Burns. "A Software Tool for Analyzing and Designing Thick Laminated Composite Structures." ARL-TR-890, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, September 1995.

² Bogetti, T. A., C. P. R. Hoppel, and W. H. Drysdale. "Three-Dimensional Effective Property and Strength Prediction of Thick Laminated Composite Media." ARL-TR-911, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, October 1995.

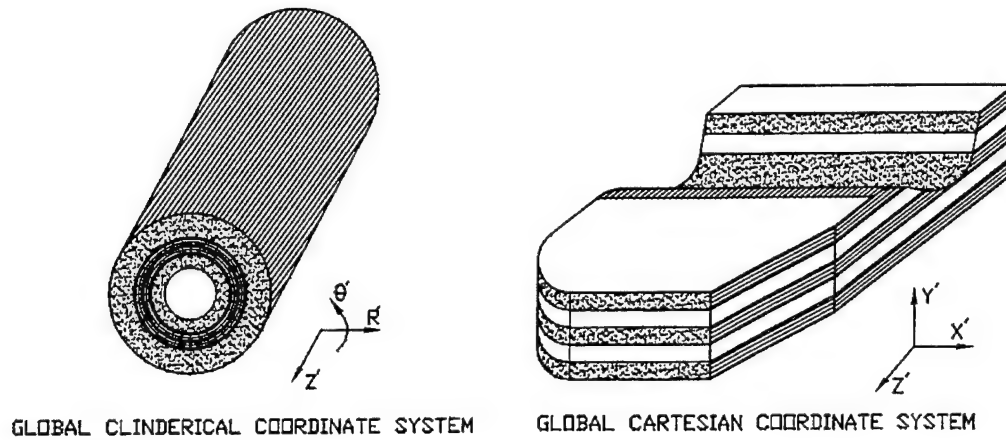


Figure 1. Typical simple laminate structures.

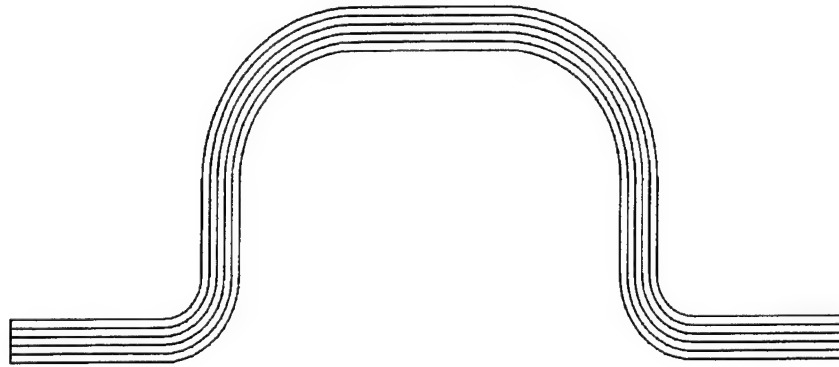


Figure 2. A laminate structure requiring more complex coordinate orientations for analysis purposes.

Figure 3 is being analyzed as a pressurized container, the radial and hoop loads of the structure should probably be observed. If the conventional approach is used, hoop stress will be S_X in some elements and S_Y in other elements. Radial stresses will behave similarly. Therefore, it will not be sufficient to plot S_X to get radial stress and S_Y to get hoop stress, but it will be necessary to plot the failure mode to see if the model is behaving properly. This may become difficult in structures with complex shapes. If the materials are oriented so that the Y (and Θ) direction for all of the elements are aligned, plotting S_X will show radial stress for all elements, and S_Y will show hoop stress for all elements.

It is easier to align the coordinate directions of the materials in the structure and observe the structure's behavior in a few plots, than it is to keep all of the regions' results and conditions and put them together like a puzzle to determine

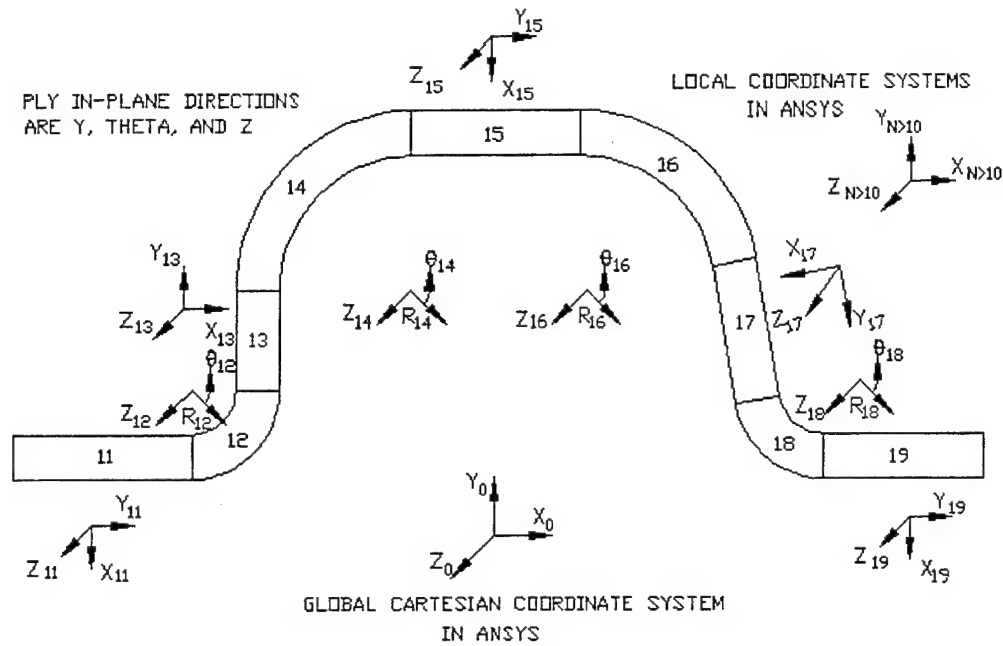


Figure 3. Alignment of local coordinate systems in ANSYS to facilitate analysis and postprocessing.

the structure's behavior. In global Cartesian coordinates in ANSYS, all elements have X, Y, and Z linear directions; stresses in postprocessing will be relative to this X-Y-Z order. When cylindrical coordinates are used either globally or locally, the order will be R- Θ -Z. Because LAMPAT uses the element coordinate systems for its transformations, it may be important to define them to be other than global Cartesian (the default system). This is particularly true when the global Cartesian system cannot properly represent the system being analyzed. But ANSYS can only specify an element's coordinate system as global Cartesian or as a LOCAL coordinate system. It is important to align the element-coordinate systems to best represent the structure under analysis. Mixed coordinate systems should be aligned to simplify postprocessing.

This report describes the method for accomplishing this task. Appendices A-E include example input files for implementing this task. The tools required for this operation include: (1) LAMPAT for preprocessing (smear) the material properties for analyzing and postprocessing the solution (unsmear) results and writing the output files, (2) ANSYS for solving the finite-element problem, and (3) macros (macro.write and macro.read) for writing and reading files from ANSYS and into it.

2. Method

To provide a simple example of modeling a structure with complex ply contours, a two-dimensional (2-D) cross section is examined. The structures can be represented as a series of arc and line segments. Several local cylindrical coordinate systems are used to describe these arcs in ANSYS. The local cylindrical coordinate system command is of the form:

LOCAL,KCN,KCS,XC,YC,ZC,THXY,THYZ,THZX,PAR1,PAR2,

where KCN is the reference number for the coordinate system (11-N),

KCS is the type of system (0 Cartesian, 1 cylindrical, 2 spherical, 3 toroidal),

XC, XY, and XZ are the global Cartesian coordinates for the center of the local system,

THXY is the rotation about local Z (X towards Y),

THYZ is the rotation about local X (Y towards Z),

THZX is the rotation about local Y (Z towards X), and

PAR1 and PAR2 are used for describing elliptical shapes.

The direction vectors for the Cartesian coordinate systems in ANSYS are X, Y, and Z. For cylindrical systems they are R, Θ , and Z, where R is the radial distance from the center of the system in the YZ plane, Θ is the angle from the X axis in the YZ plane, and Z is the distance from the XY plane.

A curved cross section of a lamina is most easily described with a cylindrical local coordinate system, as shown in Figure 4. Thus, the out-of-plane direction (3) in the local cylindrical system is X. The zero (1) and transverse (2) directions are relative to Θ and Z, which depend on the ply orientation within the laminae. For a unidirectional ply, the 1 direction would be Θ , the 2-direction Z, and the 3-direction X in the local cylindrical system. For a continuous layup along the pattern surface (Figure 3), the local coordinate systems will all use Y or Θ as the 1 direction of the ply. This is because the descriptors for the Cartesian and cylindrical coordinate systems are given in the orders of X, Y, Z and R, Θ , Z, respectively. This requires that local coordinate systems be constructed as necessary to maintain a continuity of Y and Θ for the adjacent elements in the two reference systems (Figure 4).

With the local coordinate systems (LOCAL) created and referenced (CSYS) to construct the proper geometry of the cross section and continuity of the plies, these systems must be referenced using the ESYS command while creating the

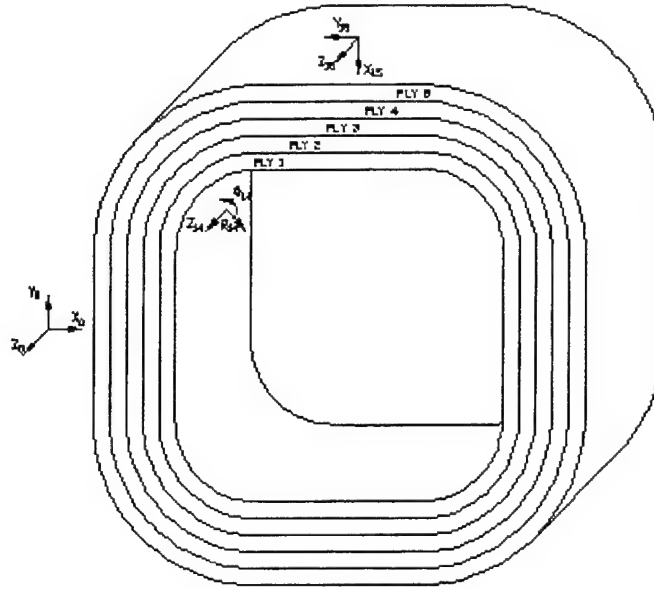


Figure 4. Curved cross-section laminate structure.

mesh (i.e., using an AMESH command). ESYS, KCN assigns a coordinate reference system to the element. The default state, ESYS, 0, assigns global Cartesian coordinates to the elements. The user may input (KCN) either 0 for global Cartesian or a local coordinate system (11-n). The local coordinate system must have been previously defined using the LOCAL command. Neither 1, 2, or 3 (global cylindrical, spherical, or toroidal) can be input to the ESYS command. Therefore, even for a model that can be built or described using the global cylindrical coordinate system, a local cylindrical coordinate system with its origin at 0, 0, 0 must be defined and referenced in the ESYS command to properly define the material properties at the element coordinate system level.

Implementing this consistent direction reference will simplify the postprocessing of the results. The resultant stresses in ANSYS are provided by default and referenced to the global Cartesian reference system. The results can be presented relative to other coordinate's systems using the RSYS command. The format of the RSYS command is RSYS, KCN. KCN can be 0 for global Cartesian, 1 for global cylindrical, 2 for global spherical, 11-n for local coordinate systems, or SOLU (in menu mode: AS CALCULATED) for reference to the element coordinate systems defined by the ESYS command. The results for any ANSYS analysis can be viewed (or printed) using RSYS (1 or 2, or 3 or 11-n). Only by using the ESYS command can the RSYS, SOLU command be used to get results at the same time relative to multiple coordinate systems. If the ESYS command is not implemented, the results relative to the single-selected coordinate system

will be applied to all elements. If no ESYS command is applied, the elements have their default elemental coordinate system, which is global Cartesian.

The following steps outline a procedure for conducting a laminate structural analysis with ANSYS and LAMPAT.

- (1) Build a model in ANSYS using the LOCAL, CSYS, and ESYS commands to provide consistent fiber orientation within each ply of the structure (i.e., model.txt). In this example, the model.txt file includes all prep7 input, except for the material property data, the solution section, and entry into post1 including selecting the results set. If the menu mode is used, the menu paths for the commands may be obtained from the help menu. Enter the command into the "Help on" window in older versions of ANSYS or enter help, "command name," in the command line in newer versions of ANSYS. At the bottom of the help page there will be a path(s) to the command entry point in the menus.
- (2) Create a material input deck for LAMPAT with the proper ply construction and orientations to match the desired directionality in the ANSYS model (i.e., 1 = Y, 2 = Z, 3 = X), (matdb.in). Note, for these analyses, that the 1 direction is considered structurally independent. That is, for example, a hoop winding is considered a "1" direction or a "0" around the mandrel, not a 90° winding as in conventional processing jargon.
- (3) Run LAMPAT as the preprocessor to create a material property input deck from matdb.in to use in ANSYS (mat.fil).
- (4) To run ANSYS interactively, start ANSYS. Click on Preprocessor. Click on Material Props. Click on Read From File. Select mat.fil. Click on File. Click on Read Input From Select model.txt. In this example, the model will be run and solved, and ANSYS will be waiting in the post1 postprocessor.
- (5) To get data for postprocessing in LAMPAT (you are still in ANSYS postprocessor), click on File. Click on Read Input From Select macro.write. This will create matid.fil and stress.fil output files. Copy or move these files where they can be used with LAMPAT.
- (6) Using the postprocessor mode in LAMPAT, input matdb.in, matid.fil, and stress.fil when prompted. Use lampat.fil as the output file. (This file name will be used later to read data into ANSYS.) Copy or move lampat.fil to where it can be accessed in ANSYS.
- (7) In ANSYS in post1, click on File. Click on Read Input From Select macro.read (this macro reads data from the lampat.fil file).

- (8) In ANSYS, execute the save command (either enter Save in the command line, or select the SAVE DB button with the mouse). This will save the etable data that is included in the file.db file, not in the result file, file.rst.

This process creates element table data to use in ANSYS postprocessing. The results in these tables will be relative to the local coordinate system for each element. Further use of the RSYS command in post1 will not affect the element table data plotting (Plot>Results>Contours>Elem table), but it will affect the data plotted in the ANSYS results files (Plot>Results>Contours>nodal or elem).

The macro.write and macro.read files are shown in Appendix E. They were written to facilitate the data transfer between ANSYS and LAMPAT. In order for all of the LAMPAT data to postprocess in ANSYS via etable data, both the macro.write and macro.read files must be utilized. The resultant etable data will be SX, SY, SZ, SYZ, SXZ, SXY, SAFE-F, FAIL-M, and CRIT-P. Three C4, C5, and C6 auxiliary files are available.

3. Conclusions

The combined use of LAMPAT and ANSYS provides a very powerful tool in analyzing laminated structures. LAMPAT's use of element coordinate systems for transforming properties and results requires that care be used in ANSYS to properly define the element coordinate systems to represent the structure under analysis. The directional properties of the materials must be properly aligned to the structure. The local coordinate systems in ANSYS, in conjunction with the ANSYS commands of ESYS and RSYS, allows for the proper modeling of laminate structures that have ply layers following simple or complex contours. With proper coordinate system rotations and ESYS and RSYS commands, continuous ply orientation along curvilinear profiles can be more easily modeled and postprocessed. This permits the stress state of a structure, such as hoop or radial stress, to be observed in a single plot in ANSYS when the RSYS, SOLU ("RSYS as computed" in menu mode) command has been issued. ANSYS cannot assign the global cylindrical as an element's coordinate system. Even when the global cylindrical coordinate system can be utilized to construct the geometry, a LOCAL coordinate cylindrical system (with its origin at 0, 0, 0) must be created to use as input to the ESYS command. The ESYS command can only accept input (KCN) as 0 or n, where n is an integer >10.

When analyzing isotropic materials in ANSYS, the ESYS command default to global Cartesian is sufficient because the directional properties are all equal. Using other coordinate system results, such as the global cylindrical coordinate system (RSYS, 1), to analyze isotropic materials will also provide the proper results.

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Appendix A. Coordinate Transformations in LAMPAT

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The rotations of BETA (β), PHI (Φ), and PSI (Ψ) correlate to the rotation of Y towards Z, Z towards X, and X towards Y, as shown in Figures A-1 and A-2. LAMPAT solves the coordinate rotations only in the order of BETA, PHI, and PSI, so there are a limited number of resultant rotations. The permutations are shown in Table A-1. The values of 2, 4, and 7 are provided only to aid in tracking the directional changes caused by the rotations. The values given for EX, EY, and EZ represent smeared elastic moduli for a nonisotropic material calculated by LAMPAT. The BETA, PHI, PSI (0,0,0) state reflects the results of the calculated directional values based on the percentage of fibers from the various fiber directions inputted for each laminate, without regard to the laminate's orientation in the structure under analysis. The laminate is oriented to the referenced coordinate system with the β , Φ , and Ψ terms. Users might configure a simple or known case, such as a unidirectional lay up, and make a trial run to understand the transformations and orientations used in their models. It may be difficult to make simple checks on complex geometry, complex lay up problems since concepts such as the 1, 2, and 3 directions become muddled. Figure A-3 shows the continuity of element coordinate direction obtained by properly assigning coordinate systems.

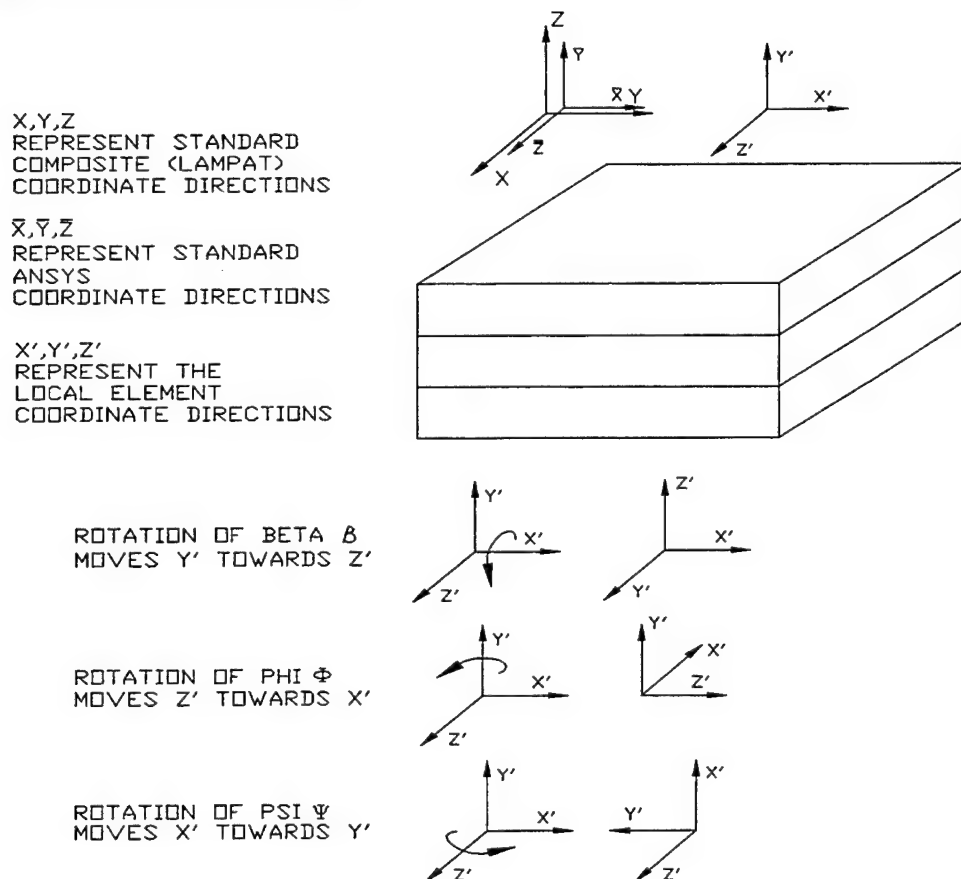
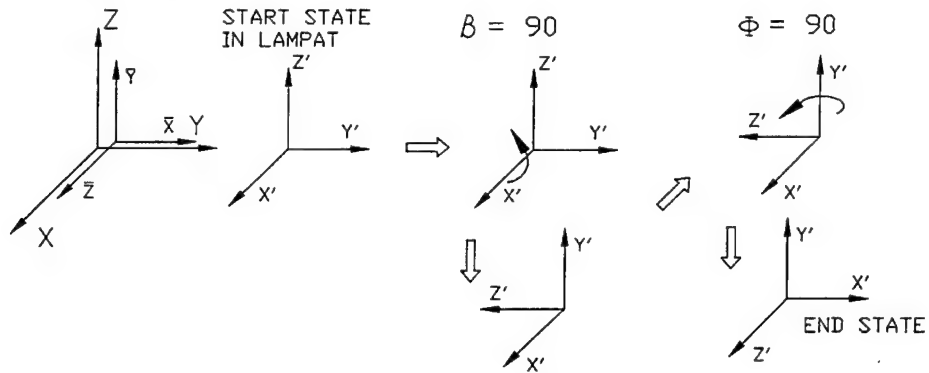


Figure A-1. Coordinate systems in LAMPAT and ANSYS.

TO GO FROM STANDARD LAMPAT TO STANDARD ANSYS COORDINATE SYSTEMS
THE ROTATION IS $\beta = 90, \phi = 90, \psi = 0$



TO GO FROM STANDARD LAMPAT TO CYLINDRICAL ANSYS COORDINATE SYSTEMS
THE ROTATION IS $\beta = 90, \phi = 90, \psi = 0$

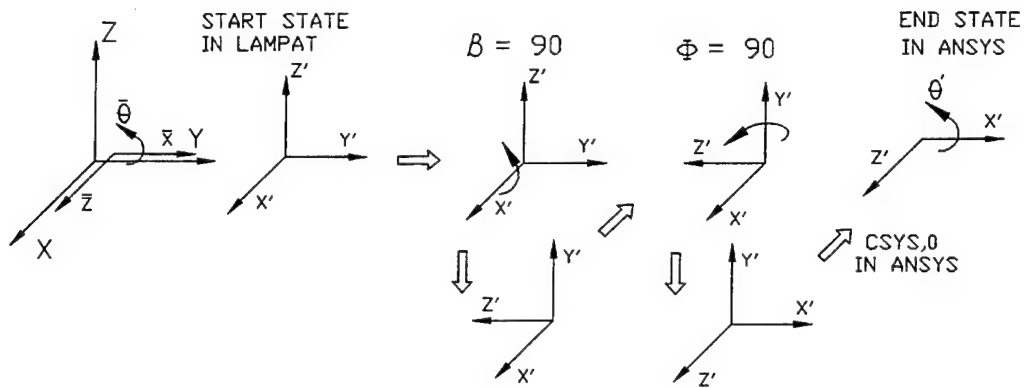
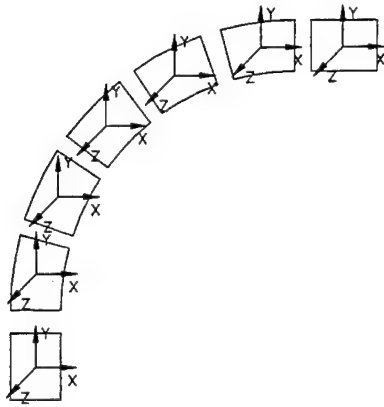


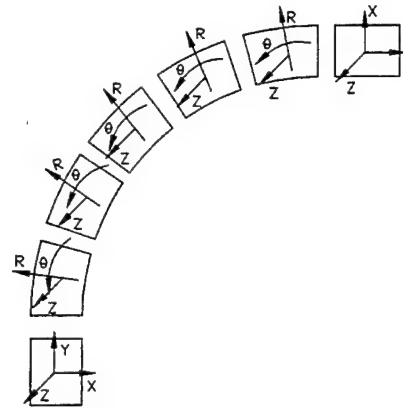
Figure A-2. Coordinate transformations for consistency within ANSYS and LAMPAT.

Table A-1. Permutations of coordinate rotations.

Orientation	1	2	3	4	5	4	3	6
BETA (Y to Z)	0	90	90	90	90	0	0	0
PHI (Z to X)	0	0	90	90	0	90	90	0
PSI (X to Y)	0	0	0	90	90	0	90	90
EX	7	7	2	2	4	2	2	7
EY	4	2	7	4	2	4	7	4
EZ	2	4	4	7	7	7	4	2



GLOBAL CARTESIAN COORDINATE SYSTEM
ELEMENT COORDINATE SYSTEMS ARE NOT
CONTINUOUS AROUND 90 DEGREE FILLET



GLOBAL AND LOCAL COORDINATE SYSTEMS
ELEMENT COORDINATE SYSTEMS ARE
CONTINUOUS AROUND 90 DEGREE FILLET

Figure A-3. Comparison of default, global Cartesian, and local coordinate systems on the element coordinate systems for alignment of laminae properties and results.

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Appendix B. Material Input for Smearing and Coordinate Transformation (DBMAT.IN)

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8				!	NO. OF REGIONS IN THE DATABASE
1				!	NO. OF MATERIALS IN DATABASE
1.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
0.0,	-90.0,	0.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
2.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
0.0,	-90.0,	0.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
3.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
0.0,	-90.0,	0.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
4.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
0.0,	-90.0,	0.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
5.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
0.0,	90.0,	90.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
6.0,	2.0,	10.0,	0.0	!	REG_ID, FAIL_CRT, ITTERS, ITEXT
90.0,	90.0,	90.0,	0.0	!	BETA_(X), PHI_(Y), SI_(Z), ---
2.0,	2.0,	0.0,	0.0	!	NPLY, REG_TYP, ---, ---
1.0,	0.005,	0.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	0.005,	90.0,	-0.0001	!	MAT_ID, THICKNESS, ANGLE, TEMP
1.0,	2.0,	1.889E-04	!	MAT_ID, MAT_TYPE, MAT_DENS(S2-GLASS/	
7.1500E+06,	2.13E+06,	2.13E+06	!	E1,	E2, E3 EPOXY)
0.499,	0.306,	0.296	!	NU23,	NU13, NU12
0.710E+06,	0.980E+06,	0.980E+06	!	G23,	G13, G12
2.300E-06,	1.850E-05,	1.850E-05	!	A1,	A2, A3
0.0,	0.0,	0.0	!(1)	VM1,	VM2, VM3 VON MISES
0.0,	0.0,	0.0	!	VM4,	VM5, VM6
0.0,	0.0,	0.0	!	VM7,	VM8, VM9
0.0,	0.0,	0.0	!	---	---
0.0,	0.0,	0.0	!	---	---
243.00E+03,	7.00E+03,	8.50E+03	!(2)	X1T,	X2T, X3T MAXIMUM
177.00E+03,	30.60E+03,	35.00E+03	!	X1C,	X2C, X3C STRESS
15.70E+03,	17.00E+03,	15.70E+03	!	X23,	X13, X12

0.0,	0.0,	0.0	!	----	----	----
0.0,	0.0,	0.0	!	----	----	----
0.0340,	0.0033,	0.0040	! (3)	Y1T,	Y2T,	Y3T MAXIMUM
0.0248,	0.0144,	0.0164	!	Y1C,	Y2C,	Y3C STRAIN
0.0221,	0.0173,	0.0160	!	Y23,	Y13,	Y12
0.0,	0.0,	0.0	!	----	----	----
0.0,	0.0,	0.0	!	----	----	----
0.0,	0.0,	0.0	! (4)	XLT,	XTT,	HPD HYDROSTATIC
0.0,	0.0,	0.0	!	XLC,	XTC,	S PRESSURE
0.0,	0.0,	0.0	!	ML1,	ML2,	LTP
0.0,	0.0,	0.0	!	MT1,	MT2,	TTP
0.0,	0.0,	0.0	!	MS1,	MS2,	STP
0.0,	0.0,	0.0	! (5)	X1T,	X1C,	--- TSAI-WU
0.0,	0.0,	0.0	!	X2T,	X2C,	---
0.0,	0.0,	0.0	!	S12,	F12,	F23
0.0,	0.0,	0.0	!	----	----	----
0.0,	0.0,	0.0	!	----	----	----
7.1500E+06,	2.13E+06,	2.13E+06	! (6)	E1,	E2,	E3 CHRISTENSEN
0.499,	0.306,	0.296	!	NU23,	NU13,	NU12
0.710E+06,	0.980E+06,	0.980E+06	!	G23,	G13,	G12
0.0,	0.0,	0.0	!	K,	ALPHA,	---
0.0,	0.0,	0.0	!	Y1T,	Y1C,	---
0.0,	0.0,	0.0	! (7)	FE1,	FE2,	FE3 FENG
0.0,	0.0,	0.0	!	FE4,	FE5,	FE6
0.0,	0.0,	0.0	!	FE7,	FE8,	FE9
0.0,	0.0,	0.0	!	FE10,	FE11,	FE12
0.0,	0.0,	0.0	!	FE13,	FE14,	FE15
0.0,	0.0,	0.0	! (8)	HA1,	HA2,	HA3 MODIFIED
0.0,	0.0,	0.0	!	HA4,	HA5,	HA6 HASHIN
0.0,	0.0,	0.0	!	HA7,	HA8,	HA9
0.0,	0.0,	0.0	!	HA10,	HA11,	HA12
0.0,	0.0,	0.0	!	HA13,	HA14,	HA15

Appendix C. Material Input for ANSYS (MAT.FIL)

This appendix appears in its original form, without editorial change.

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/COM, LAMPAT (VERSION 4.1) MATERIAL FILE FOR ANSYS 5.5

```
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EX ,      1 ,      1, 0.1130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EY ,      1 ,      1, 0.7150000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EZ ,      1 ,      1, 0.2130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,NUXY,      1 ,      1, 0.3060000E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXY ,      1 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GYZ,      1 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXZ ,      1 ,      1, 0.7099999E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXY,      1 ,      1, 0.4836084E-01,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRYZ,      1 ,      1, 0.2960001E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXZ,      1 ,      1, 0.2647277E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EX ,      2 ,      1, 0.1130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EY ,      2 ,      1, 0.7150000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EZ ,      2 ,      1, 0.2130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,NUXY,      2 ,      1, 0.3060000E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXY ,      2 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GYZ,      2 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXZ ,      2 ,      1, 0.7099999E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
```

```

MPDATA,PRXY,      2 ,      1, 0.4836084E-01,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,PRYZ,      2 ,      1, 0.2960001E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,PRXZ,      2 ,      1, 0.2647277E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EX ,       3 ,      1, 0.1130000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EY ,       3 ,      1, 0.7150000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EZ ,       3 ,      1, 0.2130000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,NUXY,      3 ,      1, 0.3060000E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,GXY ,      3 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,GYZ,      3 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,GXZ ,      3 ,      1, 0.7099999E+06,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,PRXY,      3 ,      1, 0.4836084E-01,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,PRYZ,      3 ,      1, 0.2960001E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,PRXZ,      3 ,      1, 0.2647277E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EX ,       4 ,      1, 0.1130000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EY ,       4 ,      1, 0.7150000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,EZ ,       4 ,      1, 0.2130000E+07,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,NUXY,      4 ,      1, 0.3060000E+00,
MPTEMP
MPTEMP,          1, 0.0000000E+00,
MPDATA,GXY ,      4 ,      1, 0.9800000E+06,
MPTEMP
MPTEMP,          1, 0.0000000E+00,

```

```

MPDATA,GYZ,      4 ,    1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXZ ,     4 ,    1, 0.7099999E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXY,     4 ,    1, 0.4836084E-01,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRYZ,     4 ,    1, 0.2960001E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXZ,     4 ,    1, 0.2647277E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EX ,      5 ,    1, 0.1130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EY ,      5 ,    1, 0.7150000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EZ ,      5 ,    1, 0.2130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,NUXY,     5 ,    1, 0.3060000E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXY ,     5 ,    1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GYZ,     5 ,    1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXZ ,     5 ,    1, 0.7099999E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXY,     5 ,    1, 0.4836084E-01,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRYZ,     5 ,    1, 0.2960001E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXZ,     5 ,    1, 0.2647277E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EX ,      6 ,    1, 0.1130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EY ,      6 ,    1, 0.7150000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,EZ ,      6 ,    1, 0.2130000E+07,
MPTEMP
MPTEMP,      1, 0.0000000E+00,

```

```

MPDATA,NUXY,      6 ,    1, 0.3060000E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXY ,      6 ,    1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GYZ,      6 ,    1, 0.9800000E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,GXZ ,      6 ,    1, 0.7099999E+06,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXY,      6 ,    1, 0.4836084E-01,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRYZ,      6 ,    1, 0.2960001E+00,
MPTEMP
MPTEMP,      1, 0.0000000E+00,
MPDATA,PRXZ,      6 ,    1, 0.2647277E+00,

```

Appendix D. ANSYS Input File (MODEL.TXT)

This appendix appears in its original form, without editorial change.

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If using the menu mode, the menu paths for the commands may be obtained through the help menu. Enter the command into the "Help on" window; a path(s) to the command entry point in the menus will be at the bottom of the help page.

```
/title, LAYUP: 0/90
! DEFINE MATERIAL PROPERTIES

! CHOOSE ELEMENT TYPE 2-D STRUCTURAL
et,1,42,,,0
et,2,42,,,0
et,3,42,,,0
et,4,42,,,0
et,5,42,,,0
et,6,42,,,0

! CREATE LOCAL COORDINATE SYSTEMS
! MENU PATH FOR LOCAL: Utility Menu >WorkPlane >Local Coordinate Systems
! >Create Local CS

local,11,1,-1,-1,0
local,12,1,1,-1,0
local,13,1,1,1,0
local,14,1,-1,1,0
local,15,0,0,0,0,90,0,0,

!BUILD MODEL
!CREATE GEOMETRY
!ASSIGN KEYPOINTS
!NOTE MODEL COULD HAVE BEEN BUILT BY SYMETRIES

! CREATE MODEL KEYPOINTS
csys,11
k,1,.5,270
csys,12
k,2,.5,270
k,3,.5,0
csys,13
k,4,.5,0
k,5,.5,90
csys,14
k,6,.5,90
k,7,.5,180
csys,11
k,8,.5,180
k,9,1,270
csys,12
k,10,1,270
k,11,1,0
csys,13
k,12,1,0
```

```

k,13,1,90
csys,14
k,14,1,90
k,15,1,180
csys,11
k,16,1,180

!DEFINE LINES
csys,11
l,8,1,16
l,16,9,16
csys,12
l,2,3,16
l,10,11,16
csys,13
l,4,5,16
l,12,13,16
csys,14
l,6,7,16
l,14,15,16

csys,0
l,1,2,40
l,9,10,40
l,3,4,40
l,11,12,40
l,5,6,40
l,13,14,40
l,7,8,40
l,15,16,40

l,1,9,10
l,2,10,10
l,3,11,10
l,4,12,10
l,5,13,10
l,6,14,10
l,7,15,10
l,8,16,10

!CREATE AREAS

a,9,10,2,1
a,10,11,3,2
a,11,12,4,3
a,12,13,5,4
a,13,14,6,5
a,14,15,7,6
a,15,16,8,7
a,16,9,1,8

!ASSIGN ELEMENT TYPE, MATERIALS, ELEMENT COORDINATE SYSTEMS
!CREATE MESH

! MENU PATHS FOR ESYS:

```

```
! Main Menu >Preprocessor >Create >Elements >Elem Attributes
! or Main Menu >Preprocessor >Define >Default Attribs
```

```
esys,11
mat,1
type,1
amesh,8
esys,12
mat,2
type,2
amesh,2
esys,13
mat,3
type,3
amesh,4
esys,14
mat,4
type,4
amesh,6
esys,15
mat,5
type,5
amesh,1,5,4
esys,0
mat,6
type,6
amesh,3,7,4
```

```
esys,0
```

```
! CONNECT THE MESHED AREA ELEMENTS TOGETHER
! AND COMBINE COMMON NODES
nummrg,node
```

```
! CREATE (SAVE) file.db
```

```
save
```

```
! LEAVE PREP7
```

```
fini
```

```
!ENTER SOLUTION PHASE
```

```
/solu
```

```
!USE AUTOMATIC TIME STEPPING FOR NON-LINEAR PROBLEMS.
autots,on
```

```
! CONSTRAIN STRUCTURE IN SPACE
```

```
csys,0
nsel,s,loc,y,-1.5,1.5
nsel,r,loc,x,0
d,all,ux,0
nsel,all
```

```
nsel,s,loc,y,0
nsel,r,loc,x,-1.5,1.5
d,all,uy,0
```

```

nsel,all

! APPLY INTERNAL PRESSURE TO STRUCTURE

csys,11
nsel,s,loc,x,.5
sf,all,pres,1000
nsel,all

csys,12
nsel,s,loc,x,.5
sf,all,pres,1000
nsel,all

csys,13
nsel,s,loc,x,.5
sf,all,pres,1000
nsel,all

csys,14
nsel,s,loc,x,.5
sf,all,pres,1000
nsel,all

csys,0
nsel,s,loc,x,-1.5,1.5
nsel,r,loc,y,-1,1
sf,all,pres,1000
nsel,all

csys,0
nsel,s,loc,x,-1,1
nsel,r,loc,y,-1.5,1.5
sf,all,pres,1000
nsel,all

csys,0

!SOLVE THE PROBLEM

solve

! REWRITE file.db INCLUDING SOLUTION COMMANDS

save

! LEAVE SOLUTION PHASE

fini

```

```

! ENTER POST PROCESSOR

/post1

! INPUT RESULT SET

set,1,1

! PRESENT RESULTS IN ELEMENT COORDINATE SYSTEMS

! MENU PATHS FOR RSYS:
! Main Menu > General Postproc > Options for Outp
! or Utility > List >Results> Options

rsys,solu

! PLOT AREAS

aplo

! (WAIT IN INTERACTIVE MODE)
! BEGIN POSTPROCESSING PROCEDURE FOR LAMPAT BY CREATING
! MATID.FIL AND STRESS.FIL FILES.

! AFTER READING IN THE MACRO.WRITE, POSTPROCESSING IN LAMPAT,
! AND WRITING THE ETABLE DATA WITH MACRO.READ,
! SAVE THE DATA BY WRITING TO file.db (ENTER SAVE IN THE COMMAND LINE
! OR SELECT THE SAVE DB BUTTON WITH THE MOUSE). THE ETABLE DATA IS
! WRITTEN INTO THE file.db, NOT THE file.rst FILE.

```

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Appendix E. Data Transfer Macros (MACRO.WRITE)

This appendix appears in its original form, without editorial change.

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Macro Write. This is used to write ANSYS data into files for use in LAMPAT. Associate materials and stresses with element numbers are included.

```
/com
/com
/com MACRO FOR STRESS - - - - -
/com
/com

*get,numelem,elem,,count

*dim,elenum,array,numelem,1,1
*do,i,1,numelem
  elenum(i)=i
*enddo

etable,sx,s,x
etable,sy,s,y
etable,sz,s,z
etable,syz,s,yz
etable,sxz,s,xz
etable,sxy,s,xy

*dim,esx,array,numelem,1,1
*dim,esy,array,numelem,1,1
*dim,esz,array,numelem,1,1
*dim,esyz,array,numelem,1,1
*dim,esxz,array,numelem,1,1
*dim,esxy,array,numelem,1,1

*vget,esx(1),elem,1,etab,sx
*vget,esy(1),elem,1,etab,sy
*vget,esz(1),elem,1,etab,sz
*vget,esyz(1),elem,1,etab,syz
*vget,esxz(1),elem,1,etab,sxz
*vget,esxy(1),elem,1,etab,sxy

*cfopen,stress,fil
*vwrite,elenum(1),esx(1),esy(1),esz(1),esyz(1),esxz(1),esxy(1)
/com      The following format line may vary from one LAMPAT version
/com      to another. Be sure to be consistent and large enough for
/com      your model.
(f6.0,/,6e13.5)
*cfclose

/com
/com
/com MACRO FOR STRAIN - - - - -
/com
/com
/com      Users might want to remove the macro for
/com      the strain section. Its output was not
/com      used in this example. It may consume
```

```

/com      a significant amount of time for a large model.

etable,ex,epto,x
etable,ey,epto,y
etable,ez,epto,z
etable,eyz,epto,yz
etable,exz,epto,xz
etable,exy,epto,xy

*dim,epsx,array,numelem,1,1
*dim,epsy,array,numelem,1,1
*dim,epsz,array,numelem,1,1
*dim,epsyz,array,numelem,1,1
*dim,epsxz,array,numelem,1,1
*dim,epsxy,array,numelem,1,1

*vget,epsx(1),elem,1,etab,ex
*vget,epsy(1),elem,1,etab,ey
*vget,epsz(1),elem,1,etab,ez
*vget,epsyz(1),elem,1,etab,eyz
*vget,epsxz(1),elem,1,etab,exz
*vget,epsxy(1),elem,1,etab,exy

*cfopen,strain,fil
*vwrite,elenum(1),epsx(1),epsy(1),epsz(1),epsyz(1),epsxz(1),epsxy(1)
/com      The following format line may vary from one LAMPAT version
/com      to another. Be sure to be consistent and large enough for
/com      your model.
(f6.0,/,6e13.5)
*cfclose

/com
/com
/com MACRO FOR MATERIAL ID - - - - -
/com
/com

*cfopen,matid,fil
*do,i,1,numelem
*get,m1,elem,i,attr,mat
*vwrite,i,m1
(2f13.5)
*enddo
*cfclose

```

MACRO.READ

This is used to read LAMPAT data into ANSYS for postprocessing. It transfers stresses, strains, failure mode, safety factor, ply failure, and XXXX into element data tables (etable).

```

/com

```

```

/com
/com MACRO FOR READING - - - - -
/com
/com

*get,numelem,elem,,count
numtot=numelem*7

*dim,elenum,array,numelem,1,1
*do,i,1,numelem
elenum(i)=i
*enddo

*dim,a,array,numtot,1,1
*dim,a1,array,numelem,1,1
*dim,a2,array,numelem,1,1
*dim,a3,array,numelem,1,1
*dim,a4,array,numelem,1,1
*dim,a5,array,numelem,1,1
*dim,a6,array,numelem,1,1

*vread,a(1),lampat,fil
/com      The following format line may vary from one LAMPAT version
/com      to another. Be sure to be consistent and large enough for
/com      your model.
(f6.0,/,6e13.5)

*do,i,1,numelem
k=(i-1)*7
a1(i)=a(k+2)
a2(i)=a(k+3)
a3(i)=a(k+4)
a4(i)=a(k+5)
a5(i)=a(k+6)
a6(i)=a(k+7)
*enddo

*do,i,1,numelem
desol,i,all,eppl,x,a1(i)
desol,i,all,eppl,y,a2(i)
desol,i,all,eppl,z,a3(i)
desol,i,all,eppl,yz,a4(i)
desol,i,all,eppl,xz,a5(i)
desol,i,all,eppl,xy,a6(i)
*enddo

etable,safe-f,eppl,x
etable,fail-m,eppl,y
etable,crit-p,eppl,z
etable,c4,eppl,yz
etable,c5,eppl,xz
etable,c6,eppl,xy

```

Macro.read uses the standard LAMPAT code processing data file, which is named lampat.fil prior to executing this macro. This macro writes information (safety factor data, failure mode data, and ply failure data) into etable data as plastic strain. To examine the plastic strain in the model, this must be done prior to executing the macro. The following is an alternative macro that uses the ANSYS smisc data terms as portals for the LAMPAT results.

```

/com
/com
/com MACRO FOR READING - - - - -
/com
/com

*get,numelem,elem,,count
numtot=numelem*7

*dim,elenum,array,numelem,1,1
*do,i,1,numelem
  elenum(i)=i
*enddo

*dim,a,array,numtot,1,1
*dim,a1,array,numelem,1,1
*dim,a2,array,numelem,1,1
*dim,a3,array,numelem,1,1
*dim,a4,array,numelem,1,1
*dim,a5,array,numelem,1,1
*dim,a6,array,numelem,1,1

*vread,a(1),lampat.fil
/com      The following format line may vary from one LAMPAT version
/com      to another. Be sure to be consistent and large enough for
/com      your model.
(f6.0/,/6e13.5)

*do,i,1,numelem
  k=(i-1)*7
  a1(i)=a(k+2)
  a2(i)=a(k+3)
  a3(i)=a(k+4)
/com      Since a4, a5, and a6 are currently not used, they are not read.
/com      To save time, remove them in the LAMPAT code to save time
/com      when running large models.
*enddo

/com      The selection of the variable term used to
/com      read data into the element data tables in
/com      ANSYS varies with the element type used (i.e.
/com      SOLID 42). If the user wants to get
/com      results on the smisc data, other terms should
/com      be used. Alternatively, if the user postprocesses

```

```
/com    the ANSYS data (i.e. smisc values)
/com    prior to reading in the lampat results (that
/com    is prior to executing macro.read), the results
/com    will not be corrupted by this read in data.
```

```
etable,safe-f,smisc,1
etable,fail-m,smisc,2
etable,crit-p,smisc,3
```

```
*do,i,1,numelem
detab,i,safe-f,a1(i)
detab,i,fail-m,a2(i)
detab,i,crit-p,a3(i)
*enddo
```

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1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN 3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316		
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